Title
Rapid prototyping and 3D printing of antarctic seal flipper tags

Journal
Wildlife Society Bulletin, 43(2)

ISSN
0043-552X

Authors
Frankfurter, Greg
Beltran, Roxanne S
Hoard, Matthew
et al.

Publication Date
2019-06-01

DOI
10.1002/wsb.964

Peer reviewed

Wildlife Society Bulletin 000–000; 2018; DOI: 10.1002/wsb.964

From the Field

Rapid Prototyping and 3D Printing of Antarctic Seal Flipper Tags

GREG FRANKFURTER,[1] *Karen C. Drayer Wildlife Health Center, University of California, Davis, CA 95616, USA; and Veterinary Medical Department, Wildlife Health and Technology Group, Davis, CA 95616, USA*

ROXANNE S. BELTRAN, *Department of Biology and Wildlife, University of Alaska Fairbanks, Fairbanks, AK 99775, USA; and Department of Biological Sciences, University of Alaska Anchorage, Anchorage, AK 99504, USA; and The Marine Mammal Center, Sausalito, CA 95616, USA*

MATTHEW HOARD,[2] *Department of Biological Sciences, University of Alaska Anchorage, Anchorage, AK 99504, USA*

JENNIFER M. BURNS, *The Marine Mammal Center, Sausalito, CA 95616, USA*

ABSTRACT Recent miniaturization of biologging devices has enabled widespread efforts to document the vertical and horizontal movements of pinnipeds; however, the attachment methods have been slower to evolve. We used rapid prototyping to develop a novel, adaptable flipper tag that could be used to deploy a biologging tag on seals that would remain attached through the annual molt cycle. The prototype flipper tag was designed using three-dimensional (3D) modeling software and produced using 3D printing. Two tags were deployed on adult, female Weddell seals (*Leptonychotes weddellii*) in McMurdo Sound, Antarctica, during the Austral Summer 2015. One animal did not return to the study area. The other tag was successfully recovered after 341 days. Upon tag removal, the flipper holes were well-healed with no evidence of pressure necrosis or irritation. This tag will provide opportunities to gain insight about animal behaviors during the annual molt, when annual hair loss precludes instrument attachment by glue. The rapid expansion of 3D printing design, material, and manufacturing tools has enabled the development of new tools for wildlife studies. © 2019 The Wildlife Society.

KEY WORDS 3D design, Antarctica, biologging, *Leptonychotes weddellii*, McMurdo Sound, rapid prototyping, tagging, Weddell seal.

Flipper tags are commonly used by researchers, rehabilitators, and managers to uniquely identify marine mammals (Bradshaw et al. 2000, McMahon and White 2009). Most often, cattle ear tags or other livestock tags are used because they are durable, designed for outdoor use on animals, easily applied, and inexpensive (Testa and Rothery 1992, Lander et al. 2001). These tags are designed to fit loosely in the relatively thin, cartilaginous ear tissue of cows, sheep, and goats, so their use in the thicker flipper webbing of pinnipeds can be problematic. The use of these "one size fits all" conventional tags can lead to early tag loss, pressure necrosis, and infection (Testa and Rothery 1992, Bradshaw et al. 2000, Pistorius et al. 2000). Additionally, the semiaquatic lifestyles of pinnipeds cause further challenges for conventional flipper tags because most rely on a single point of attachment, which makes heavier or larger tags more vulnerable to loss associated with underwater drag or abrasion when hauled out. Tag loss precludes unique animal identification and increases uncertainty in estimating demographic parameters from mark–recapture studies.

Recent technological advances have dramatically reduced the size and mass of telemetry and archival devices (i.e., very-high-frequency [VHF] transmitters, satellite tags, accelerometers, Global Positioning System recorders, and Time–Depth Recorders [TDRs]) used to study animal behavior and movements. This has opened the door to new attachment methods, such as deployment on flipper tags, which offer the advantage of longer deployments than gluing to fur. When standard livestock tags are inadequate platforms for the electronics, new attachments can be custom-made to meet the specific needs of a project (e.g., Wildlife Computers, Bellevue WA, USA, SPOT tag base). To date, most custom bases have been made through an injection molding process, which requires development and construction of an expensive (US$3,000–$10,000) mold. The advantage of this method is that once the mold is complete, tag bases are inexpensive to produce in high volume; however, low volume production becomes cost-prohibitive because the initial cost of the mold cannot be recuperated. More importantly, modifications are impossible after mold creation. This limits

Received: 22 August 2018; Accepted: 19 January 2019
Published: 00 Month 2019

---

[1] *E-mail: gfrankfurter@ucdavis.edu*

[2] *Present address: California Academy of Sciences, San Francisco, CA 94118, USA.*

the ability of researchers to alter tag bases following prototype deployments or to adapt the tag base for different species. Computer-aided machining (CAM) can be used for smaller numbers of parts, but requires extensive time for initial setup and changes. Other approaches such as three-dimensional (3D) printing circumvent these problems; however, their use had previously been limited due to production costs and limited equipment availability.

To investigate the year-round energetics of female Weddell seals (*Leptonychotes weddellii*) in Antarctica, we glued archival biologging instruments to cattle ear tags (Original Temple Tag, Temple, TX, USA), which we then attached to a rear flipper of each seal (Beltran et al. 2017). During initial tag recoveries, it became apparent that in some cases, tags were causing pressure-induced tissue necrosis that slowed healing and occasionally resulted in tag and data loss. Previous deployment of Temple-tag-mounted devices as part of this project had a tag loss rate of 8/67 tags (~12%). We frequently used a single-hole attachment strategy because the temple tag height was insufficient to accommodate the thicker tissue in the upper flipper webbing. This precluded a 2-hole attachment method that may have reduced drag and increased retention. In the few instances where pressure necrosis associated with tag attachment appeared to slow healing, we removed tags if still present or recorded them as lost. Unfortunately, removing the Temple tag destroyed the tag base, preventing instruments from being rapidly redeployed. Instead, instruments had to be returned to the laboratory, reconditioned, and reattached to a new tag before attachment to another animal.

To improve tag retention rates and facilitate rapid reuse, we desired a different attachment method. The desired parameters included a tag base that would 1) allow for attachment of a biologging instrument, 2) provide adequate spacing to eliminate pressure necrosis and allow for proper healing, and 3) be easily attached and removed for reuse. The tag also had to meet the durability requirements of deployment within the Antarctic marine environment, including withstanding air temperatures below −40° C, resilience to abrasion and impact, and frequent submersion in −1° C seawater for extended periods at depths >800 m. Tags would only be deployed on a limited number of animals, so design flexibility was required to facilitate future refinement based on retention success. Therefore, we used 3D printing to develop functional flipper-tag prototypes for deployment on Weddell seals.

STUDY AREA

We captured 2 Weddell seals on the sea ice in McMurdo Sound, Antarctica (approx. 77°S, 166°E). The ocean temperature in this region was −1.9° C, and air temperature overwinter can reach −40° C.

METHODS

We designed a 2-part tag measuring 46-mm length × 16.5-mm width × 7.5-mm post height in Autodesk Inventor 3D software (Autodesk, Mill Valley, CA, USA; Fig. 1). The taller post height relative to Temple tags (6.2 mm) allowed for a 2-hole attachment technique without risk of compression of the more proximal flipper tissue. We produced tags from PA-650 Nylon-12 (Advanced Laser Materials, Temple, TX, USA) using Selective Laser Sintering on a sPro-60 Printer (3D Systems, Rock Hill, SC, USA) by Proto Labs Incorporated (Maple Plain, MN, USA). We pressed 2 #8–32 stainless steel threaded inserts (Snapsert #832SR8-6; Yardley Products, Yardley PA, USA) into the "female" tag part (Fig. 1). We affixed a VHF transmitter (Sirtrack, Havelock North, NZ) weighing 22 g to each tag using a 2-part epoxy (Devcon Plastic Welder; ITW Polymers Adhesives, Danvers, MA, USA) and allowed to harden for ≥24 hr before deployment.

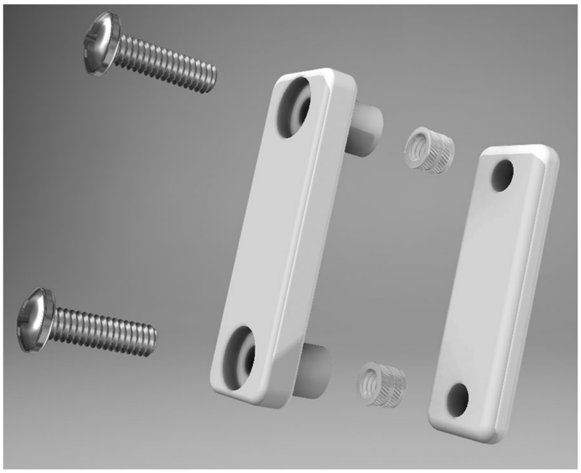

Figure 1. Exploded view of custom flipper-tag assembly, used to attach telemetry device to Weddell seal flippers in McMurdo Sound, Antarctica, during the Austral Summer 2015. The prototype flipper tag (46-mm length × 16.5-mm width × 7.5-mm internal height) was designed using three-dimensional (3D) modeling software and produced using 3D printing.

We deployed prototype tags on 2 free-ranging Weddell seals during the Austral Summer 2015. On 7 December, the first tag was deployed on a 15-year-old female seal (ID 14498), and on 9 December, the second prototype was deployed on a 14-year-old female, ID 14488. We captured and anesthetized animals as described in Shero et al. (2014). For deployment, we placed 2 holes 35 mm apart (to correspond with the distance between the tag posts) in the rear flipper of the seal using a sterile leather punch in the webbing between digits. We secured the tag in the holes using #8–32 stainless steel screws (Fig. 2).

Animal handling protocols were approved by the University of Alaska Anchorage and Fairbanks Institutional Animal Care and Use Committee approvals #419971 and #854089. Research and sample import to the United States was authorized under National Marine Fisheries Service Marine Mammal permit #17411. Research activities were approved through Antarctic Conservation Act permit #2014-003.

RESULTS

We completed initial tag design in approximately 12 hr. The first printed prototypes were available within 48 hr of design completion. We made several subsequent revisions to the tag before final printing. Total costs for production were US$2,450 for development and US$1,022 for printing and

Figure 2. Dorsal (left) and ventral (right) views of prototype flipper tag with very high frequency transmitter after 341 days of attachment to Weddell seal flipper in McMurdo Sound, Antarctica, during the Austral Summer 2015. Upon tag removal, flipper holes were well-healed with no evidence of pressure necrosis or irritation, demonstrating an improvement over conventional flipper-tag attachments.

finishing. These costs were 73% and 91% lower than CAM and injection molding, respectively.

Seal 14498 was recaptured 341 days after tag deployment. The animal was briefly restrained in a hoop net, and the flipper tag was recovered intact by unscrewing the tag base. Upon tag removal, the flipper holes were well-healed with no evidence of pressure necrosis or irritation. This animal also had a TDR placed using a Temple tag in 2015 at the same time as our 3D printed tag. The TDR had fallen off the Temple tag, so could not be recovered. This has not been a common issue with Temple tag attachments, but does speak to the harsh conditions and potential risks associated with these deployments. The second seal, 14488, did not return to the area in subsequent years and was unavailable to be checked for tag retention.

DISCUSSION

We demonstrated the successful use of 3D printing to rapidly and inexpensively design a durable tag for phocid seals that can easily be attached and removed. The decreasing costs of 3D printing along with an increasing number of materials provide new opportunities for wildlife managers and researchers to design custom tools for biologging attachment. Indeed, 3D printing has been used to develop a splint for a radius and ulna fracture in a sea turtle (*Chelonia mydas*; Christiansen et al. 2014), a prosthetic bill for a toucan (*Ramphastos dicolorus*; Krassenstein 2015), and turtle (Testudine) eggs with embedded transponders to catch poachers (Baraniuk 2017).

Using traditional production methods such as CAM and injection molding, applications requiring a single or small number of devices can be costly and time-prohibitive. Once completed, injection molds often cannot be easily altered; therefore, customization for different projects and species will incur the same initial setup costs. Parts made through computer-aided machining have similarly high setup costs, though may be more easily altered in the future. The estimated cost for the design and deployment of a tag is less for 3D printing than injection molding and CAM (Fig. 3), although cost differences will vary based on material selection, finishing, and other manufacturing parameters (i.e., size of production runs, shape and size of pieces, accuracy and tolerance requirements, color choices).

Injection molding, CAM, and 3D printing have advantages, disadvantages, and capabilities that must be considered for each. For example, while 3D printing offers flexibility in design and customization, 3D printed parts are usually less precise than those produced by CAM. In contrast, while 3D printing offers advantages for small and specialized lots, it may become less cost-effective as number of parts reaches the hundreds or thousands; here, injection molding may be more appropriate (Fig. 3). In our case, 3D printing proved to be the best production method because of the small number of parts needed, limited need for high precision, and requirement of making alterations (e.g., post height) for specific deployment applications.

In summary, we used 3D printing to develop a functional prototype that allowed for deployment and recovery of costly biotelemetry devices in harsh conditions. Although only 2 prototypes were deployed, the production method allows us to easily alter and reprint prototypes to meet future needs. As 3D printing technologies advance, decreasing cost, increasing speed, and increasing materials available for

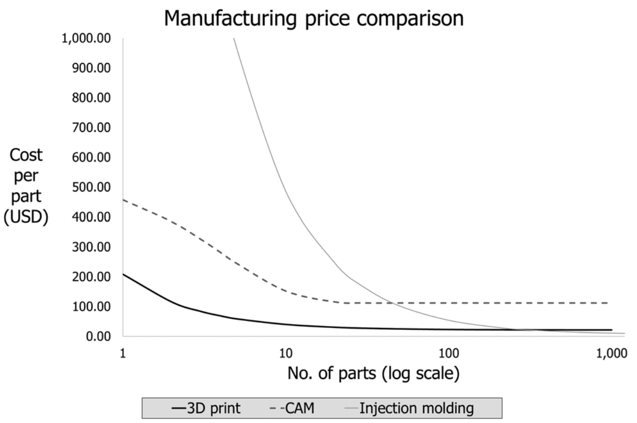

Figure 3. Cost comparison for three-dimensional (3D) printing, Computer-Aided Machining (CAM), and Injection molding relative to number of parts produced for custom flipper tag for Weddell seal flipper in McMurdo Sound, Antarctica, during the Austral Summer 2015.

printing will further improve our ability to use this technology for worldwide research and conservation efforts.

ACKNOWLEDGMENTS

We thank the B-009-M field team led by Drs. R. Garrott and J. Rotella for their help with animal identification, and the B-292-M field team led by J.M.B for assistance with handling procedures. Thank you to Associate Editor E. Glenn for editorial review and comments, and to T. Boal and J. Wallace for thoughtful advice and comments, and to the reviewers for their feedback and critique. This project was made possible by logistical support provided by the National Science Foundation United States Antarctic Program, Lockheed Martin Antarctic Support Contract, and support staff in Christchurch, New Zealand, and McMurdo Station. This study was conducted with financial support from ANT-1246463 to J.M.B. and J.W. Testa. This material is based upon work completed while serving at the National Science Foundation (J.M.B). Any opinion, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors state no conflict of interest regarding the material contained within this paper.

LITERATURE CITED

Baraniuk, C. 2017. Fighting tooth and nail. New Scientist 233(3118):22–23.

Beltran, R. S., J. W. Testa, and J. M. Burns. 2017. An agent-based bioenergetics model for predicting impacts of environmental change on a top marine predator, the Weddell seal. Ecological Modelling 351:36–50.

Bradshaw, C. J. A., R. J. Barker, and L. S. Davis. 2000. Modeling tag loss in New Zealand fur seal pups. Journal of Agricultural, Biological, and Environmental Statistics 5:475–485.

Christiansen, E. F., D. J. Marcellin-Little, A. Issacs, T. J. Horn, R. L. Aman, C. Legner, and C. A. Harms. 2014. A customized 3D-printed splint for stabilization of an open front flipper fracture in a green sea turtle (*Chelonia mydas*). IAAAM, Gold Coast, Australia

Krassenstein, E. 2015. A 3D printed beak saves this toucan's life. 3DPrint.com. <https://3dprint.com/90498/3d-printed-toucan-beak/>. Accessed 22 Mar 2019.

Lander, M. E., A. J. Westgate, R. K. Bonde, and M. J. Murray. 2001. Tagging and tracking. Pages 851–880 *in* L. A. Dierauf, and F. M. D. Gulland, editors. CRC handbook of marine mammal medicine. Second edition. CRC Press, New York, New York, USA

McMahon, C. R., and G. C. White. 2009. Tag loss probabilities are not independent: assessing and quantifying the assumption of independent tag transition probabilities from direct observations. Journal of Experimental Marine Biology and Ecology 372:36–42.

Pistorius, P. A., M. N. Bester, S. P. Kirkman, and P. L. Boveng. 2000. Evaluation of age- and sex-dependent rates of tag loss in southern elephant seals. Journal of Wildlife Management 64:373–380.

Shero, M. R., L. E. Pearson, D. P. Costa, and J. M. Burns. 2014. Improving the precision of our ecosystem calipers: a modified morphometric technique for estimating marine mammal mass and body composition. PLoS One 9:e91233. https://doi.org/.

Testa, J. W., and P. Rothery. 1992. Effectiveness of various cattle ear tags as markers for Weddell seals. Marine Mammal Science 8:344–353.

Associate Editor: Glenn.